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# A Towed Sledge for Benthic Surveys

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# Introduction

For many years the Marine Laboratory Aberdeen (MLA) has used towed sledges (Fig. 1) to carry underwater cameras for studying the sea bed and conducting quantitative surveys of benthic flora and fauna.

The value of towed sledges as viewing platforms for benthic and behaviour studies is well documented (Chapman (ed), 1985; Newland *et al.*, 1989). The design has evolved with experience and the most recent version is described in this pamphlet. It is based on work by Holme and Barrett (1977), and the significant feature is that the cameras are mounted to have a clear view of the sea-bed in front of the sledge runners. It has been used extensively since 1978 in the North Sea and around the Scottish coastline to monitor the stocks of scallops (*Pecten maximus*), mussels (*Mytilus edulis*), common crab (*Cancer pagurus*) and, in particular, the Norway lobster (*Nephrops norvegicus*).

The sledge has also been used to study the spawning grounds of herring (*Clupea harengus*) and artificial reefs and to monitor sludge, munition and industrial waste dump sites (Bailey *et al.*, 1993; Pinn *et al.*, 1997). Plate Ia shows a mussel bed in the Dornoch Firth at a depth of 8 m, Plate Ib starfish on another section of the bed, and Plate II (a and b) a *Nephrops* ground at Bell Rock at 30 m depth. These are typical of pictures obtained with the sledge and illustrate its value.

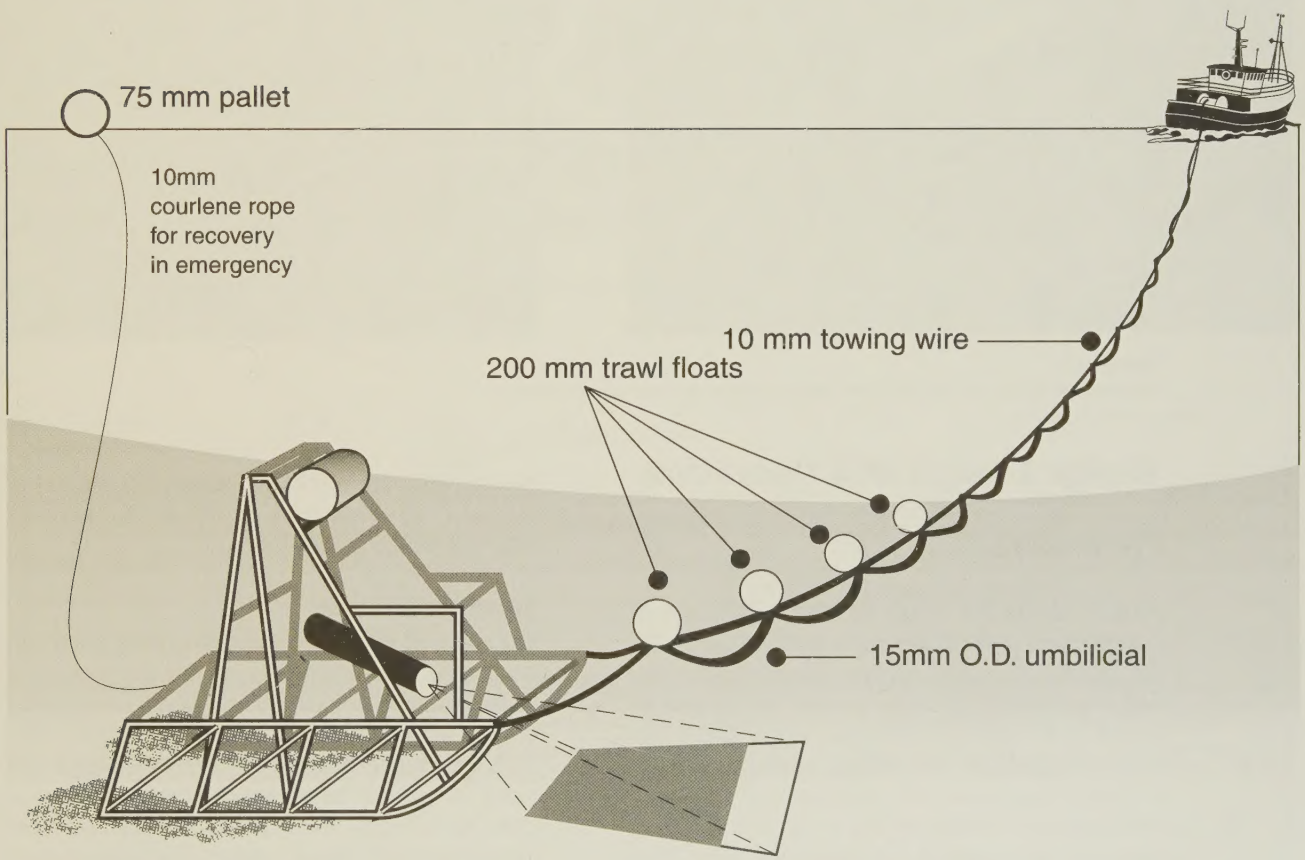


*Figure 1.*
*Towed sledge with composite towing wire and electric cable.*

*Plate I.*
*Mussel (Mytilus edulis) beds in the Dornoch Firth were surveyed by the sledge: a) to estimate the population density; and b) to investigate predation by the starfish (Asterias rubens).*

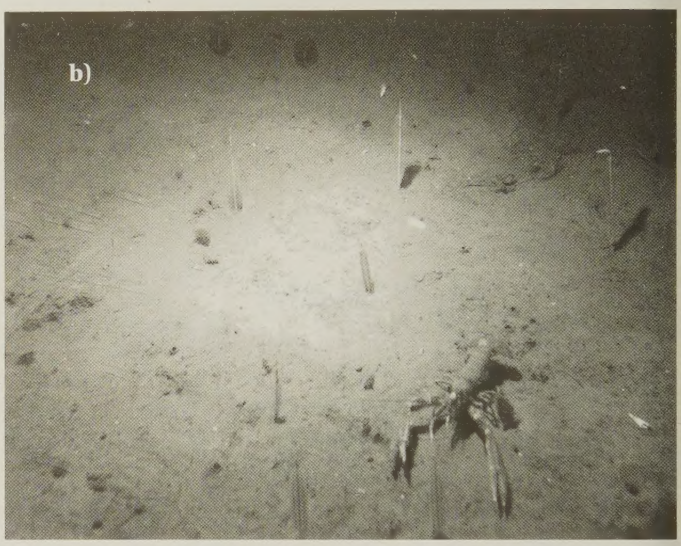


*Plate II a,b.*
*Nephrops grounds are regularly surveyed to estimate population density.*

## Sledge Design and Operation

### *Framework*

Plate III shows the sledge on land. It is of robust construction, made of salt water resistant (grade HE 30) aluminium tubing, 60 mm diameter and 5 mm wall thickness in the lower section and 38 mm diameter and 3 mm wall thickness in the upper section. The tubing is acid etched, primed and epoxy coated to maximise protection against corrosion. Welded to the bottom of the sledge are two mild steel runners to protect the aluminium tubes from abrasion. A buoyancy tank is mounted near the top to keep the sledge upright in the water whilst being deployed. The dimensions of the sledge are shown in Figure 2. The weight of the sledge with camera equipment mounted is 127 kg in air and 55 kg in water. The bottom skids wear and have to be replaced every two years, on average, but the rest of the frame has proved to be durable and has not been altered from the initial design.

### *Towing Cables*

The standard towing cable is 600 m long and incorporates the electric cables to operate the equipment on the sledge. This cable has an internal Kevlar strain bearing member of 2,000 kg tensile strength and is 25.5 mm in overall diameter. Enclosed within the outer waterproof jacket are conductors of several types and sizes for video, power, lighting and other instrumentation. Figure 3 shows this cable in cross-section. The sledge is normally used on research vessels which have slip ring winches for handling such electric cables. These winches allow the sledge to be deployed and recovered quickly and efficiently during surveys. On smaller commercial vessels which are unlikely to have a slip ring winch, the composite

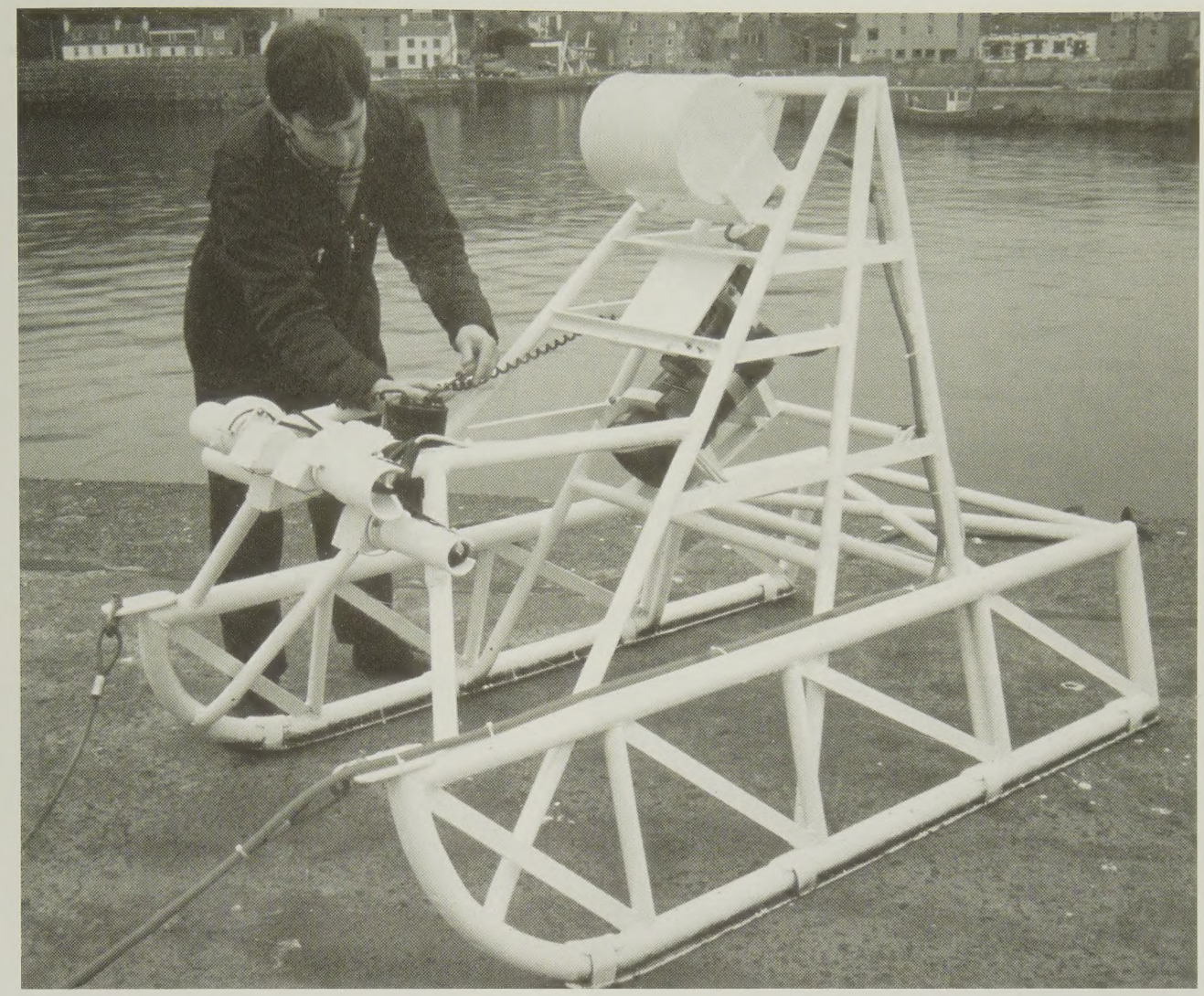

*Plate III.*
*The towed sledge showing the robust aluminium framework, buoyancy chamber, TV and still cameras in position.*

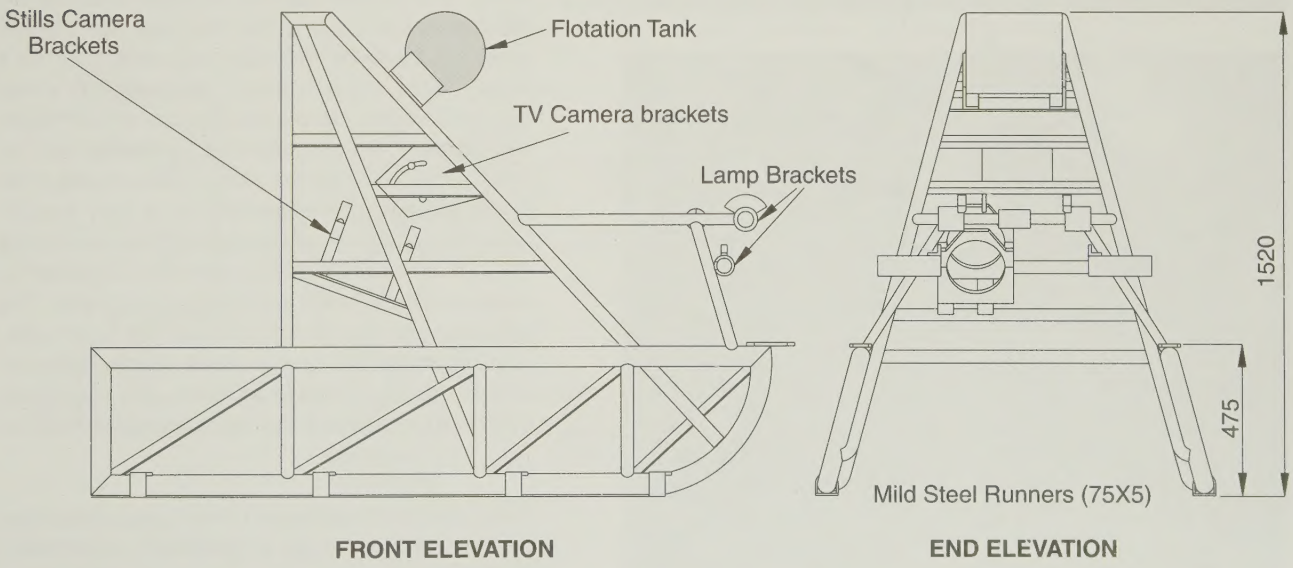


*Figure 2.*
*Scale drawing of sledge framework (side and end elevations).*

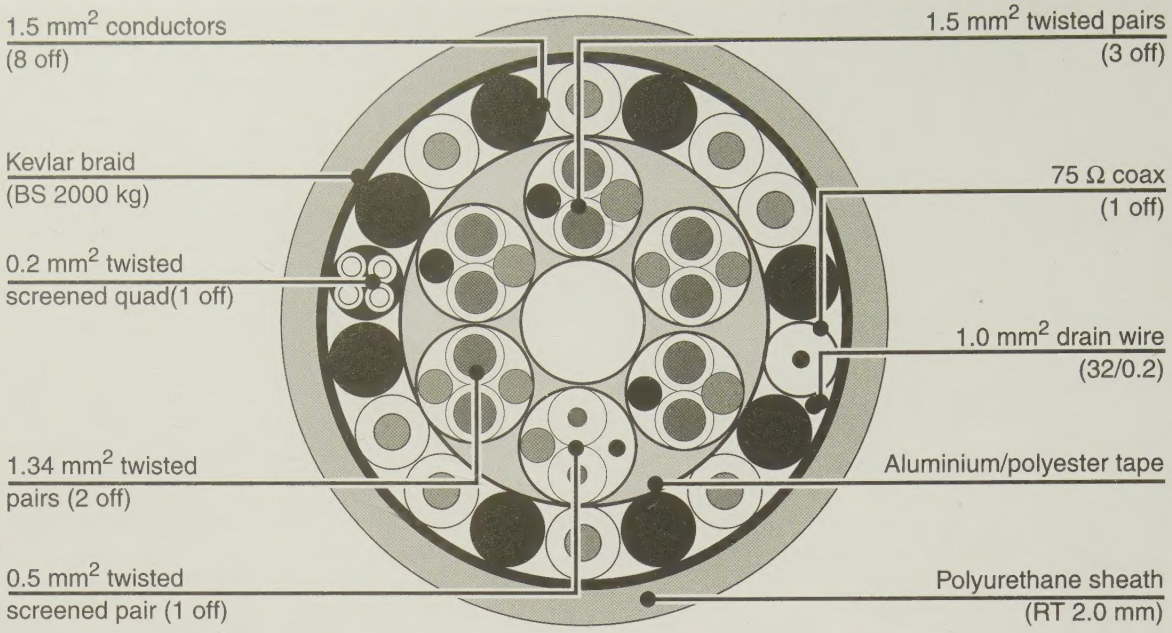


*Figure 3.*
*Cross-section of umbilical cable with integral Kevlar core for towing.*

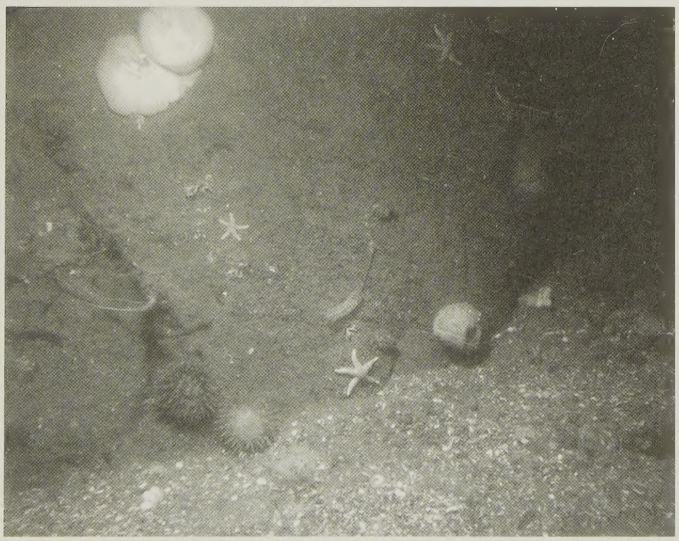

*Plate IV.*
*Boulders over which the sledge can be towed without damage.*

cable cannot be used and a multi-core electric cable is attached to a 10 mm towing wire. This cable is deployed by hand and attached every 5 m for the first 20 m and thereafter every 20 m using a slip knot. Small floats are attached at regular intervals for the first 50 m to prevent the looped cable from striking and disturbing the sea bed ahead of the sledge.

## *Deployment and Towing*

The sledge can be deployed easily from both large and small vessels. To prevent the sledge from spinning as it drops to the sea bed and to keep the towing wire under tension as it is paid out, the vessel steams slowly ahead into the wind at about 2 to 3 knots. Speed is then reduced to around one knot for detailed examination of the sea bed, and slightly faster, 1.5 knots for wider coverage of an area. At a slower speed, 0.5-0.75 knots, observation is easier and most objects on the sea bed can be identified. Towing speed is best controlled by towing into the wind and tide so that the vessel is developing more thrust and has more steerage way. A warp length/water depth ratio of two to three is used depending on surface conditions, with more warp required to counteract the vessel's motion in a heavy swell. The sledge weighs only 55 kg in water. This factor combined with the slow towing speed and the wide runners enable the sledge to be towed over large boulders without suffering damage or coming fast (Plate IV).

Since there is a significant risk of losing the sledge when towing on rough or previously unsurveyed grounds, there are two security features. Attached to the rear of the sledge is enough 10 mm courlene rope to reach the surface with a 750 mm circumfer-

ence orange buoy. If the towing cable should part, the sledge could be recovered using this rope. When operating in shallow water, less than 20 m, a 27 kHz diver homing pinger is fitted; in deeper water, this is replaced by a 57 kHz pinger, which can be tracked by the sonars on the Laboratory's vessels. If the recovery rope was also lost in an accident, the vessel could grapple on the position given by the pinger.

In common with all unpowered towed vehicles, this sledge lacks manoeuvrability and the inability to stop and examine interesting objects in detail is a handicap. This could be overcome partially by mounting the cameras and lights on a steerable platform on the sledge, but with some loss of robustness. A more complex approach would be to carry a small self-powered vehicle on a short umbilical to inspect interesting areas more closely.

## Underwater Cameras

### *Television Camera*

Depending on the aims of a project, either a monochrome or a colour camera is used. The monochrome camera is a Hydro Products SDA 125 type, fitted with a 25 mm silicon diode array tube giving 600 lines resolution. The front port is corrected for refraction and the camera has a 2.5 mm f1.4 auto iris lens, giving corrected horizontal and vertical angles of 53° and 41° respectively. When colour images are required, an Osprey 1364 CCD (charge coupled device) camera is used. This model was chosen for its high definition (460 lines) and good object resolution at a light intensity of 0.1 lux. The advantage of a CCD camera in this application is that it offers good sensitivity over short viewing distances, (1 to 2 m) combined with robustness. Both types of TV camera are focused remotely from the surface and have auto iris adjustment.

The television camera is mounted above and ahead of the still camera, on a tiltable bracket looking slightly ahead of the field of view of the still camera. The towing umbilical provides power to the camera and carries the video signal to a time and date generator, U-Matic video recorder and display screen (Fig. 4). An Osprey Cyclops control unit (OE 1211A) may be used to store two pages of text, useful for labelling the video tapes, adding the ship's position and other data.

### *Still Camera*

The still photographic camera is a Hasselblad body fitted with a motor drive, 50 mm f4 lens and a 70 exposure film cassette, within an aluminium underwater housing, depth rated to 450 m. The housing is mounted on the sledge at a fixed angle of 30° to the horizontal. The 50 mm Zeiss Distagon lens has an in-air diagonal angle of 75° giving a usable picture area in water about 75 cm wide by 100 cm long (Fig. 5). Thus the area viewed obliquely by both cameras

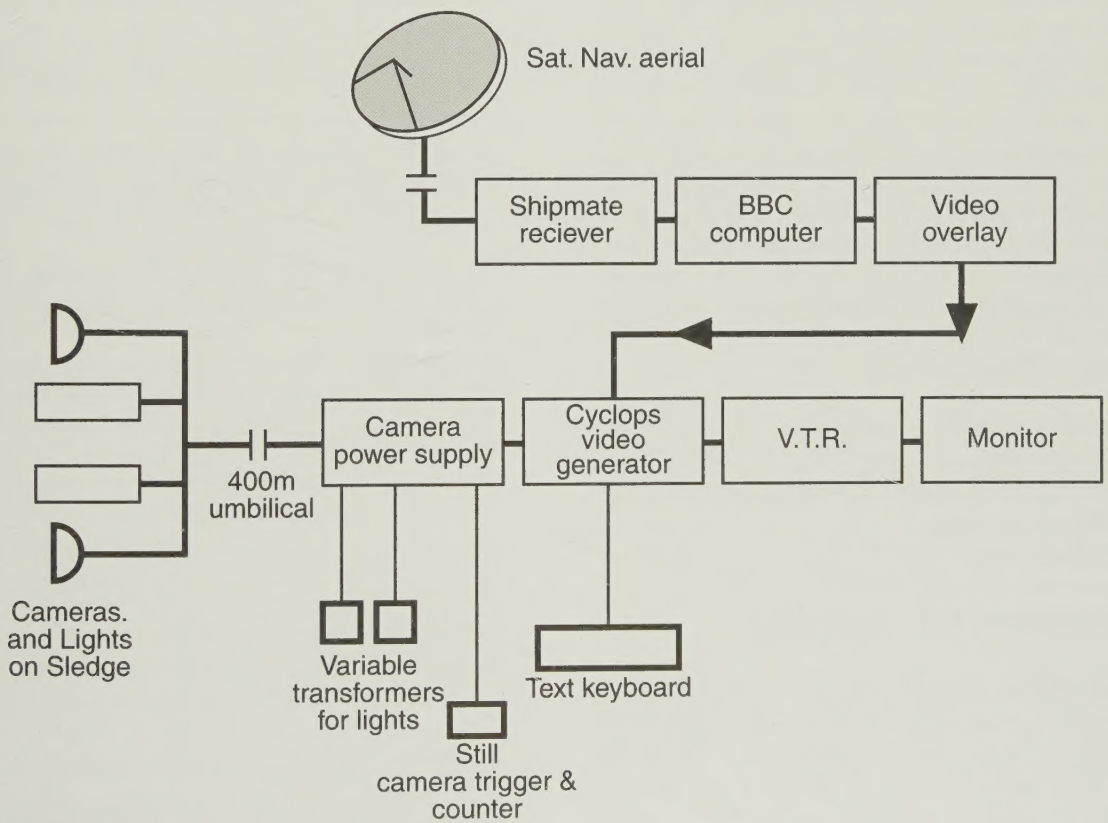


*Figure 4.*
*Control and monitoring system for the sledge.*

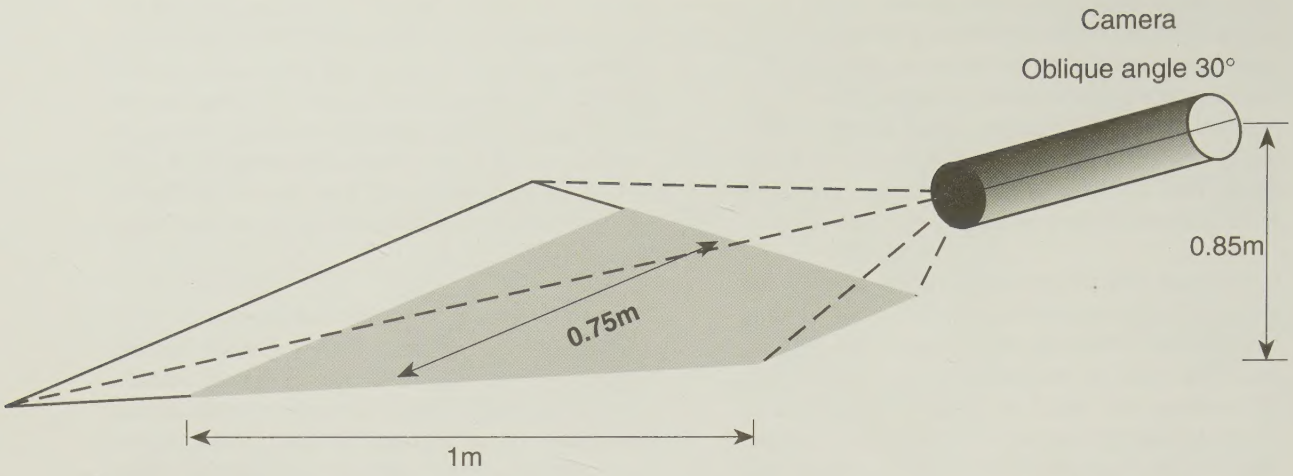


*Figure 5.*
*Sea bed area observed by cameras.*

is trapezoidal, not rectangular. Mounting the cameras like this gives better perspective and early warning of foul ground ahead. It is not practical to illuminate the entire field of view, so the upper third of each photograph is underexposed. The television camera, looking slightly ahead of the still camera, is used as a viewfinder for the Hasselblad camera. The operator triggers the Hasselblad when a target appears in the lower half of the television picture. The number of exposures taken is logged automatically.

High definition images are particularly important for species identification in benthic and pollution studies. The Hasselblad camera takes 57 mm square pictures which are larger and give higher resolution than those from a 35 mm camera. These pictures can also be enlarged without loss of definition which aids identification. Prior to sealing the camera in its housing, the shutter speed, aperture and focus are selected for the expected optical conditions. When using 400 ASA colour negative film (Kodak SO/200) the camera shutter is set at 1/60 s and the lens at f11, focused at 1.37 m (corrected for refraction in water). At f11 and 1.37 m the depth of field is between 1.06 and 2.28 m.

Before deployment the cameras and lights are always tested on deck by photographing a clapper board showing cruise, date, tow number and film information.

## Underwater Lighting

Natural light intensity is rarely adequate for underwater cameras to obtain useful images. Artificial lighting must be provided, continuously for TV cameras and by flash for still photography. It can often be difficult, however, to illuminate underwater scenes effectively. Sea water normally contains plankton, silt and other suspended particles which absorb and scatter light (Glover *et al.*, 1977). The choice and positioning of lights to cope with these effects is crucial to obtaining good images. In dark conditions, Glover showed that when lights are 2 m from a target, the incident light level may be only 1% of the radiated intensity due to absorption and scattering. A practical working distance for adequate illumination is therefore around 1 m. Even at this distance, light intensity is reduced by about 90%. Further, absorption is a function of colour. Red light is absorbed at approximately six times the rate of blue/green light in water. Thus distant underwater images from a colour television camera have a mainly blue/green tint. Even in the clearest water, red colours are usually extinguished in natural light below 10 to 20 m depth. The same effect is apparent with artificial light and, as viewing range increases, a colour camera shows a change in colour balance. Chapman (1985) used red lights to avoid blinding *Nephrops* whose eyes are sensitive to white light.

When the light source and camera are mounted close together and pointed directly at the subject, the light scattered by suspended particles is reflected directly back along the camera axis (Fig. 6a). The effect on the television picture can be like looking through falling snow. On still photographs the backscattered light appears as many discrete bright points. To minimise backscatter, the lights on the sledge are mounted at the front, well ahead of the camera, pointing almost vertically downwards to illuminate only the target area (Fig. 6b). Some light scattered by particles in the water still reaches the cameras, however, and creates a uniform background level of illumination known as flare. When particle densities are high this can markedly reduce contrast in the images. Flare can be reduced in still photographs by positioning the subject close to the edge of the illuminated zone.

Illumination for the still camera is provided by two stroboscopic flash guns (Osprey OE 4000A) synchronised to the camera shutter. These units are self-

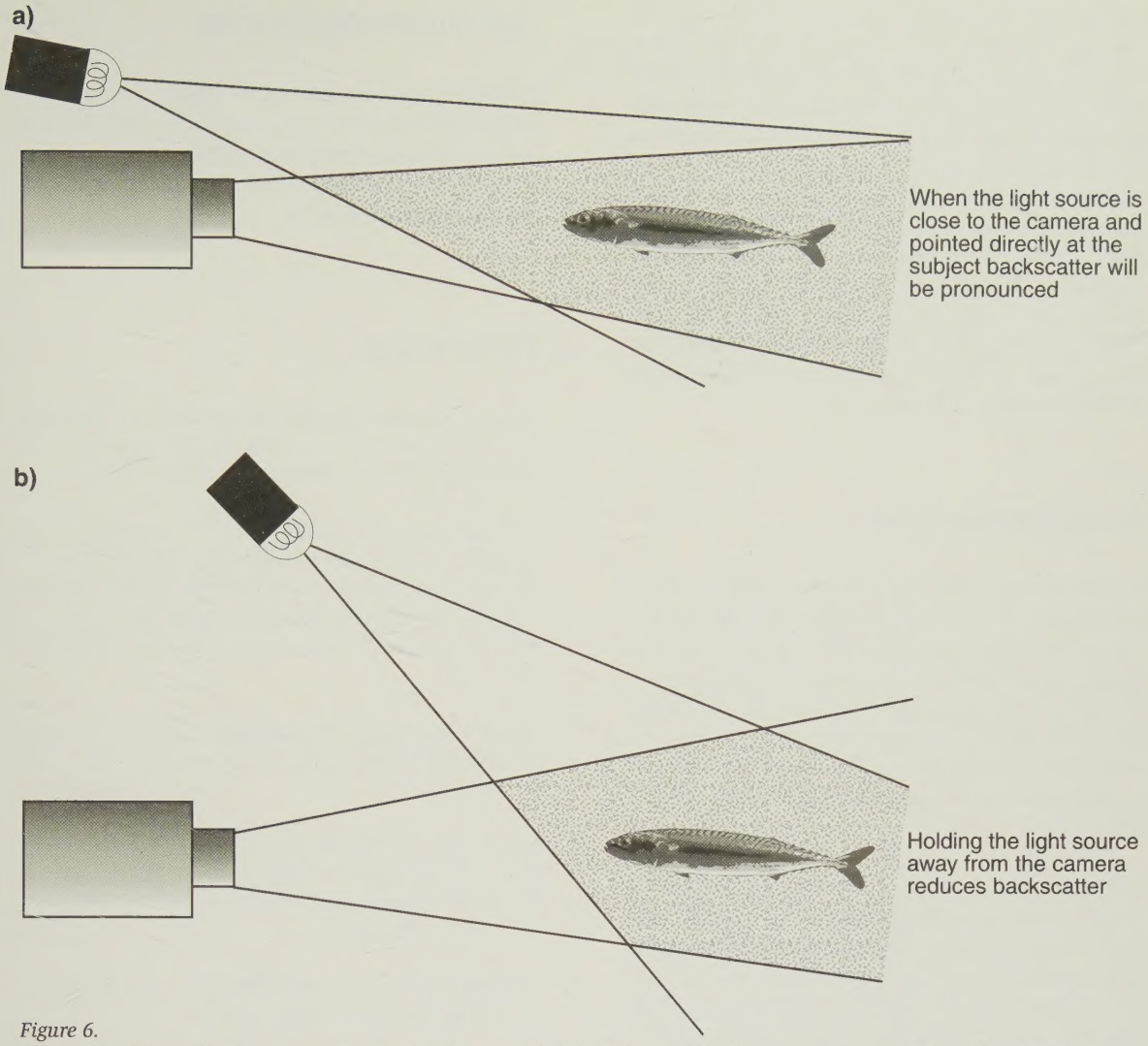
a)
When the light source is close to the camera and pointed directly at the subject backscatter will be pronounced
b)
Holding the light source away from the camera reduces backscatter

*Figure 6.*
*Effect of position of light source on backscatter by suspended particles: a) high backscatter level; and b) reduced backscatter.*

contained, powered by internal nickel cadmium rechargeable batteries, and capable of 200 flashes per charge. Depth rated to 450 m, each has an output of 65 Joules. One unit is mounted at the front of the sledge pointing vertically downwards and the other is further back pointing obliquely at the target area.

On the front of the sledge are four mounting brackets which allow the TV lamp angles to be adjusted, and which protect the bases and connectors. The lamps (Versabeam lamps, Remote Ocean Systems, USA) have quartz iodide bulbs (120 V, 500 W, 52° beam). The lamps are controlled from the surface, by a variable transformer, which can compensate for voltage drop in the cable. On a cable length of 400 m, the drop could be 30 V, seriously decreasing spectral output and illumination level. Adjusting the transformer can also decrease flare, should backscatter be a problem.

Quartz iodide incandescent lamps have several advantages for underwater lighting. They give a wide colour range in water due to high energy output in the red part of the spectrum. Light is produced less than one second after switching on, important for behaviour studies which require lighting to be turned on and off quickly. Replacement bulbs are relatively cheap, readily available and easily replaced at sea. The disadvantage of this type of lamp is that it is easily damaged when shaken, eg when the sledge bumps over large boulders or rock outcrops. To avoid damage in areas of rough sea-bed, more robust mercury vapour lamps are used.

Mercury vapour lamps have no internal filament or coil, unlike incandescent lamps. A high voltage electric arc ionizes argon gas in the tube and the heat generated vaporises mercury droplets. From ignition, these lamps take 12 minutes to reach full brightness. Another disadvantage is that, if the arc is extinguished accidentally, it cannot be restored quickly. A cooling period is needed to allow the mercury vapour to condense on the tube walls and allow the vapour pressure to fall sufficiently to restrike the arc. This cooling period is approximately five minutes for a 250 W lamp and is followed by the warm up time of 12 minutes to full brilliance. This type of lamp is more efficient than an incandescent lamp,

radiating 50 lumens/W compared to 15 lumens/W. The spectral output of a mercury vapour lamp is closely matched to the spectral characteristics of sea water, with lower absorption and hence better target visibility than incandescent lamps, (Mertens *et al.*, 1970). Further, the spectral output does not change with supply voltage as does that of an incandescent lamp. No red light is emitted by a mercury vapour lamp, so it is less useful for observations requiring knowledge of colours. The high cost of this type of lamp makes it unsuitable for general use. Both types of lamp are designed for use underwater and overheat rapidly in air. They can only be switched on momentarily on deck for test.

## Instrumentation

Instruments are attached to record distance travelled, penetration of the sledge runners into the sea bed and water depth. An odometer, with a 1 m circumference aluminium wheel, is mounted at the rear of the sledge to measure distance travelled. Each revolution triggers a reed relay linked to a recorder on the vessel. To avoid damage, the wheel can be raised or lowered. A mechanical counter provides a back-up record.

The physical size of an object may be determined from a TV or photographic image if the exact distance from camera to object is known. The sledge may lose contact with the sea bed or sink into it, so the camera to sea bed distance is constantly changing. An acoustic range finder (Remote Marine Systems Ltd) is fixed to the sledge frame and gives an accurate reference measurement (accuracy ± 5 mm at 1500 m/s). Mounted next to the range finder is a pressure transducer (Druck PDCR910) to measure water depth. Signals from the odometer, range finder and pressure transducer are transmitted through the umbilical cable to the towing vessel and recorded on a ship-board computer together with time date and vessel position.

## Acknowledgements

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